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Genetic improvement through mass selection in madura local maize (*Zea mays* L.), Indonesia

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Mass selection is a breeding method used to increase the productivity of two Madura local maize. The study used a Randomized Complete Block Design (RCBD), repeated three times with ten genotypes of treatment. The plant material used was ten genotypes of the 0^{th} to 4^{th} generation mass selection on two Madura local maize (cultivars: Tambin and elos), i.e., T-C0, T-C1, T-C2, T-C3, T- C4, E-C0, E-C1, E-C2, E-C3, E-C4. Heritability values in the broad sense of the ten observed characters have a high category, ranging from 0.65-0.97. Production per hectare has a significant positive correlation with the character of ear length, ear circumference, ear diameter, seed weight per plant, and weight of 1000 seeds. Mass selection on two Madura local maize for four cycles showed an increase in production of 611.20 kg/ha or an average selection response of 145.16 in the tambin cultivar, while in the elos cultivar, there was an increase in production of 754.55 kg/ha or an average selection response of 179.21. Mass selection of tambin and elos cultivars in four cycles decreased days to tasseling by -1.33 days (the average selection response is -0.22) and -1.00 days (the average selection response is -0.16), respectively. Mass selection is an effective breeding method for assembling maize varieties with early maturity and high production on tambin and elos cultivars.
Keywords: Heritability, the correlation between characters, selection response, mass selection, madura local maize.

INTRODUCTION

The land for maize cultivation in Madura island, East Java Province - Indonesia, is dominated (> 90%) by local cultivars, while other areas in East Java Province are dominated (> 70%) by superior varieties (open-pollinated variety and hybrids) (Amzeri, 2018). The use of local cultivars, which is broad, causes maize productivity in Madura island to be very low (2.15 t/ha) (BPS-Statistic, 2020). The previous exploration and research found 16 Madura local maize, with a potential production of 2.55 - 3.84 t/ha (Amzeri *et al.*, 2011). Increasing Madura local maize productivity through breeding methods is the right solution to increase maize productivity in Madura. The utilization of local maize as genetic material in a variety assembly is highly recommended to expand the genetic background of superior varieties. Mass selection is one of the breeding methods used to increase the productivity of Madura local maize. Mass selection is a genetic improvement method that plant breeders often use to improve plant characteristics (Muntean *et al.*, 2022).

Mass selection in maize plants was carried out by selecting individual plants based on the phenotype of the random mating population (Shrestha *et al.*, 2018). Mass selection aims to increase the desired traits by increasing the frequency of the desired genes (Merrick *et al.*, 2020). The genetic diversity in the initial population limits the increase in gene frequency in mass selection. The result of mass selection is an increase in the average performance of the base population. Assembling varieties through mass selection is done by selecting one or several selections by planting plants in small plots. Each plant was planted in small plots to reduce environmental diversity, which could affect the genetic differences of plants observed (Hallauer *et al.*, 2010). Mass selection methods have been shown to increase yield (Baktash, 2016), yield components (Sudika *et al.*, 2018), and reduce the desired agronomic character (Hussanun et al., 2016) on maize plants.

Variety assembly through selection will result if the enhanced characters have high heritability values (Azis *et al.*, 2018; Faisal *et al.*, 2022; Marwan *et al.*, 2022). Heritability is a key parameter in quantitative genetics that determines the value of the selection response (Piepho and Mohring, 2007; Suwarti *et al.*, 2022; Sudika *et al.*, 2023). The high heritability value will increase the selection response to the selected plant characters. The research results showed that a high heritability value increased the selection response by 4.29% on the

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character of the maize oil content (Corona *et al.,* 2015), and the production per hectare by 1.76% (Mejaya and Lambert, 2016).

Determining the correlation between characters is used as the basis for the efficiency of the selection program (Azad et al., 2012; Nascimento-Junior *et al.,* 2018; Muliadi *et al.,* 2021). Two or more characters that have a positive correlation will facilitate the selection program because an increase in a character will be followed by other characters (Kuswantoro *et al.,* 2018). This study aims to evaluate the agronomic performance of the mass selection of two Madura local maize, Indonesia.

MATERIALS AND METHODS

***Plant material and Procedure*:** The research was conducted in Augustus - November 2022 during the rainy season in Bangkalan Regency, East Java Province - Indonesia (longitude: 112044 E; latitude: 7007 S, altitude: 5 m; soil type: Grumusol). The plant material used was ten genotypes of the 0^{th} to 4^{th} generation mass selection on two local Madura maize (cultivars: Tambin and elos), i.e., T-C0, T-C1, T-C2, T-C3, T- C4, E-C0, E-C1, E-C2, E-C3, E-C4. The intensity of selection in each cycle of mass selection on both cultivars was 10%. A randomized complete block design (RCBD) was used with ten genotypes as a single factor and replicated three times, so there were 30 experimental units. Each genotype was planted in plot size 4 x 5 m with a 70 x 25 cm spacing. Each square contained 120 plants. Fertilization was carried out in three stages: (1) The first fertilization was given at seven days after planting, i.e., 100 kg/ha urea, 200 kg/ha SP-36, and 50 kg/ha KCl, (2) The second fertilization was given at 21 days after planting, i.e., 100 kg/ha Urea and 50 kg/ha KCl, and (3) The third fertilization at 35 days after planting (100 kg/ha urea).

***Data Collection and Statistical Analysis*:** Observations were made on 20 plants per experimental plot. The observed characters were plant height (PH), days to tasseling (DT), days to silking (DS), ear height (EH), ear length (EL), ear circumference (EC), ear diameter (ED), seed weight per plant (SWP), weight of 1000 seeds (W1000S), production per hectare (PPH).

Data were analyzed using analysis of variance followed by the Least Significant Difference test (LSD) at $\alpha = 0.05$ (Table 1). Analysis of variance was calculated using MSTAT-C software.

Heritability values in the broad sense are calculated based on the estimated mean square values in the analysis of variance (Hill *et al.,* 1998). Heritability value in a broad sense is calculated using the formula:

$$h^2_{bs} = \frac{\sigma^2_g}{\sigma^2_g + \sigma^2_e}$$

Where h^2_{bs} was heritability value in a broad sense; σ^2_g was genotype variance; σ^2_e was environmental variance. Furthermore, heritability is classified: high ($h^2 \geq 0.5$), moderately ($0.20 \geq h^2 > 0.50$), low ($h^2 < 0.20$) (Mc Whirter, 1979). The relationship value between the observed characters used the simple correlation formula from Singh and Chaudary (1997). Simple correlation coefficient value used the formula :

$$rx.y = \frac{Cov.x.y}{\sqrt{\sigma^2 x.\sigma^2 y}}$$

Where rx.y was the correlation of the observed characters x and y, Cov.x.y was the variance of x and y, σ^2x was the variance of x, and σ^2y was the variance of y. The selection response is calculated using the formula: $R = S.h^2$, where R was the selection response, S was the differential selection, and h^2 was the heritability (Falconer, 1989).

Table 1. Analysis of variance of the characters observed in ten genotypes of maize.

Source of diversity	Free degrees	Sum of squares	Mean square	Expectation of mean square
Block	r-1	SSr	MSr	$\sigma^2e+r\sigma^2g+g\sigma^2r$
Genotype	g-1	SSg	MSg	$\sigma^2e+r\sigma^2g$
Error	(r-1)(g-1)	SSe	MSe	σ^2e
Total	(gr-1)			

Note: r = replication; g = genotype; SS = Sum of Square; MS = Mean Square

RESULTS AND DISCUSSION

***Mean values of several quantitative characters of four generations of Madura maize cultivars (Tambin and Elos cultivars)*:** The selection causes an increase in gene frequency and genotypic frequency for the selected and improved characters. In this study, the mass selection activity aims to obtain varieties with early maturity and high production characteristics so that there is expected to be a decrease in harvest age and an increase in production in mass selection activities. Early maturity can be measured by assessing the days to tasseling, because Kinfe *et al.* (2016) research shows a significant positive correlation between the days to tasseling and harvest age in maize plants. The characters of plant height, days to tasseling, days to silking and ear height in two cultivars (tambin and elos) decreased in four cycles (Table 2). These result were in line with the research of Shrestha *et al.* (2018). The character of plant height decreased by 10.32 cm, days to tasseling was 1.33 days, days to silking age was 1.33 days, and ear height was 3.29 cm. In the elos cultivar, the plant height decreased by 10.34 cm, days to tasseling was 1.00 days, days to silking was 1.33 days, and ear height was 4.24 cm. The ear lenght showed an increase in four cycles, i.e., 1.23 cm (tambin cultivar) and 1.22 cm (elos cultivar). Linear regression model for the characters of plant height, days to tasseling, days to silking, ear height, and ear length on two cultivars (Tambin and Elos) are shown in Figures 2-4.

Table 2. Mean of plant height, days to tasseling, days to silking, ear height, and ear length for several generations of mass selection.

Genotype	Plant Hight (cm)	Days to tasseling (day)	Days to silking (day)	Ear height (cm)	Ear length (cm)
T-C0	191.33 a	35.33 a	38.33 a	94.33 a	13.10 b
T-C1	187.33 ab	35.33 a	37.33 b	94.01 a	14.23 a
T-C2	185.67 bc	34.67 ab	37.00 b	92.33 a-d	14.12 a
T-C3	182.33 bc	34.00 b	37.00 b	91.67 bcd	14.23 a
T-C4	181.01 cd	34.00 b	37.00 b	91.04 cd	14.33 a
The difference between C0 and C4	-10.32	-1.33	-1.33	-3.29	1.23
E-C0	184.67 bc	34.67 ab	37.33 b	94.67 a	12.11 c
E-C1	181.67 cd	34.00 b	37.00 b	93.36 abc	13.07 b
E-C2	181.03 cd	34.00 b	37.00 b	92.67 a-d	13.23 b
E-C3	177.02 de	34.00 b	36.67 bc	91.33 cd	13.33 b
E-C4	174.33 e	33.67 b	36.00 c	90.43 d	13.33 b
The difference between C0 and C4	-10.34	-1.00	-1.33	-4.24	1.22
CV (%)	1.02	1.28	1.15	1.19	1.26
LSD (0.05)	5.22	1.17	0.92	2.65	0.50
F-test	**	*	**	**	**

Note : T = Tambin cultivar; E = Elos cultivar; * = significant in a α level of<0.05; ** = significant in a α level of<0.01; the numbers followed by the same letter in the same column are not significantly different according to the 5% LSD test

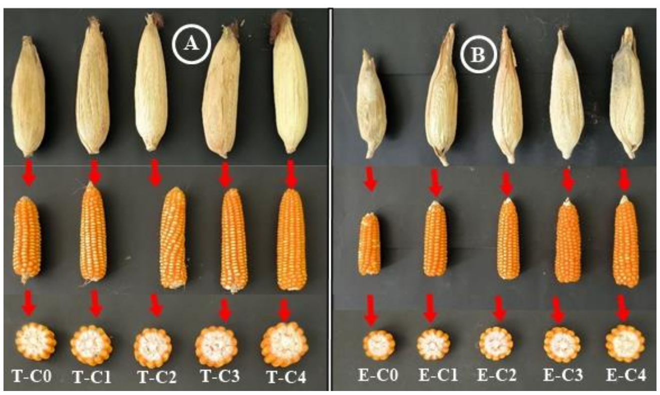

Figure 1. Appearance of maize cobs in four cycles of mass selection (a) Tambin (Tbn-0-1); (b) Elos (Es-0-1).

The ear circumference, ear diameter, seed weight per plant, the weight of 1000 seeds and production per hectare on two cultivars (tambin and elos) increased in four cycles (Table 3; Figure 1). These results were in line with Tulu and Jifar (2010) research. In the tambin cultivar, the character of the ear circumference increased by 1.30 cm, ear diameter was 0.50 cm, seed weight per plant was 13.85 g, the weight of 1000 seeds was 29.31 g, and the production per hectare was 611.20 kg. In the elos cultivar, the character of the ear circumference increased by 1.41 cm, ear diameter was 0.74 cm, seed weight per plant was 14.51 g, the weight of 1000 seeds was 29.16 g, and the production per hectare was 754.55 kg. Linear regression models for ear circumference, ear diameter, seed weight per plant, the weight of 1000 seeds, and production per hectare for two cultivars (Tambin and elos) are shown in Figures 5-6.

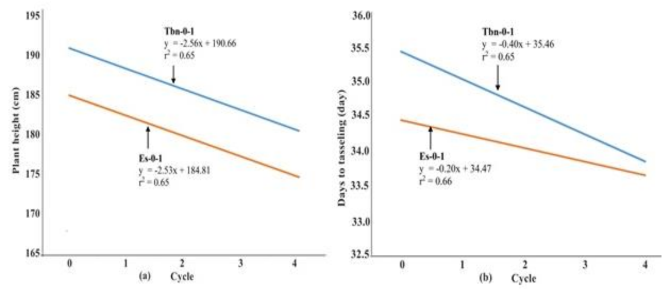

Figure 2. (a) Linear graph of the Plant height character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles; (b) Linear graph of the days to tasseling character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivar in four mass selection cycles.

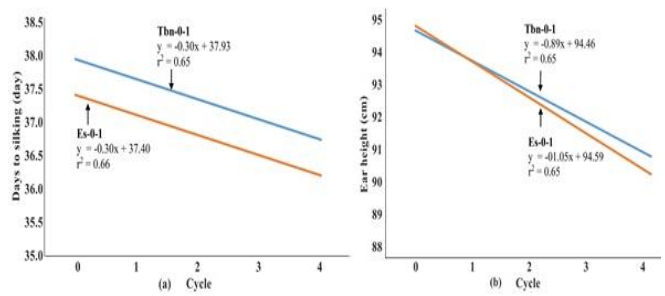

Figure 3. (a) Linear graph of the Days to silking character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles; (b) Linear graph of the ear height character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivar in four mass selection cycles.

Table 3. **Mean of ear circumference, ear diameter, seed weight per plant, the weight of 1000 seeds and production per plant for several generations of mass selection.**

Genotype	Ear circumference (cm)	Ear diameter (cm)	Seed weight per plant (g)	Weight of 1000 seeds (g)	Production per hectare (kg)
T-C0	11.37 b	3.27 c	49.02 c	230.31 d	3437.73 e
T-C1	12.47 a	3.63 ab	58.81 b	250.22 abc	3861.71 ab
T-C2	12.57 a	3.70 ab	61.51 ab	253.47 abc	3985.57 a
T-C3	12.61 a	3.73 ab	61.97 ab	255.83 ab	4025.37 a
T-C4	12.67 a	3.77 ab	62.87 a	259.62 a	4048.93 a
The difference between C0 and C4	1.30	0.50	13.85	29.31	611.20
E-C0	11.32 b	3.13 c	46.22 d	215.71 e	2987.42 f
E-C1	12.43 a	3.62 b	58.23 b	241.62 cd	3530.53 de
E-C2	12.53 a	3.67 ab	59.51 b	242.13 cd	3637.61 cde
E-C3	12.61 a	3.73 ab	60.43 ab	244.73 bc	3711.52 bcd
E-C4	12.73 a	3.87 a	60.73 ab	244.87 bc	3741.97 bc
The difference between C0 and C4	1.41	0.74	14.51	29.16	754.55
CV (%)	0.86	2.26	1.62	1.90	1.95
LSD (0.05)	0.31	0.24	2.74	13.59	211.02
F-test	**	**	**	**	**

Note: T = Tambin cultivar; E = Elos cultivar; * = significant in a α level of<0.05; ** = significant in a α level of<0.01; the numbers followed by the same letter in the same column are not significantly different according to the 5% LSD test

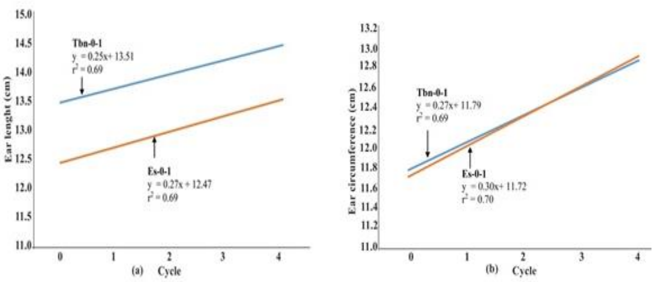

Figure 4. **(a) Linear graph of the ear length character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles; (b) Linear graph of the ear circumference character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivar in four mass selection cycles.**

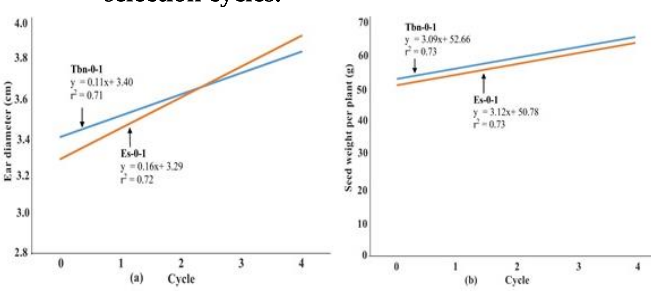

Figure 5. **(a) Linear graph of the ear diameter character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles; (b) Linear graph of the seed weight per plant character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles.**

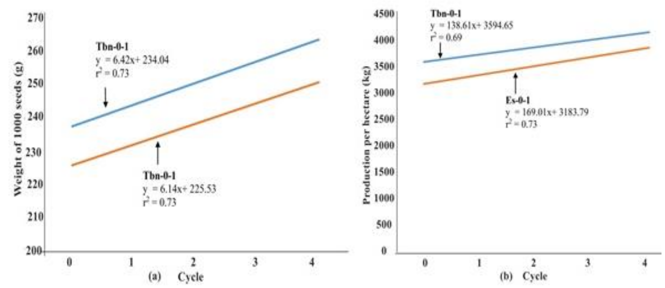

Figure 6. **(a) Linear graph of the weight of 1000 seeds character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles; (b) Linear graph of the production per hectare character of the Tambin (Tbn-0-1) and Elos (Es-0-1) cultivars in four mass selection cycles.**

Heritability**:** The heritability of a character is the proportion of genetic variance to the amount of phenotypic variance (genetic variance plus environmental variance) (Yunandra *et al.*, 2017). The heritability value can be used to measure the value of the genetic influence on the plant character value (Edy *et al.*, 2019). Heritability values in the broad sense of the ten observed characters ranged from 0.65-0.97 (Table 4). The ten maize genotype characters tested had high criteria based on heritability criteria. Characters with high heritability values indicate that genetic factors play a more important role in determining phenotypic variation than environmental factors (Badami *et al.*, 2020; Mustafa *et al.*, 2021). The selection of ten maize characters has a high chance of genetic

advancement because the selected characters are strongly controlled by genetic factors (Ullah *et al.*, 2012).

***Correlation between characters*:** Production per hectare is the main character in maize because this character has economic value. Plant breeding programs often use indirect selection to increase plant production by selecting characters that correlate with plant production (Oliviera *et al.*, 2020; Xhulaj and Gixhari, 2020; Xhulaj and Koto, 2022). The correlation coefficient which has a positive number indicates that an increase in one character will be followed by an increase in other characters. On the other hand, a negative correlation coefficient indicates that an increase in one character will decrease another character. Production per hectare has a significant positive correlation with the character of ear length, ear circumference, ear diameter, seed weight per plant, and weight of 1000 seeds (Table 5).

The production character per hectare has a non-significant negative correlation with days to tasseling character. The negative correlation value between production per hectare and the character of days to tasseling, although not significantly, indicates that increasing production per hectare will decrease days to tasseling. Mass selection to obtain early maturity and high-yielding maize varieties was very effective on Madura maize cultivars (tambin and elos) because an increase in production per hectare could reduce harvesting age as indicated by a decrease in days to tasseling.

Selection Response: Selection response is the difference between the mean population of the selected population and the population before selection with the heritability value of the observed plant characters. The selection response describes the genetic progress obtained from the selection results. (Ijaz *et al.*, 2022) The genetic advance of the selection results is caused by an increase in the frequency of genes in the selected characters (Bekele and Rao, 2014; Magar *et al.*, 2021; Shrestha *et al.*, 2021). The results of mass selection for four cycles on tambin cultivar showed genetic advance in the characters ear length (0.29 cm), ear circumference (0.32 cm), ear diameter (0.10 cm), seed weight per plant (3,36 g), weight of 1000 seeds (6.45 g), production per hectare (145.16 g) (Table 6). The results of mass selection for four cycles on elos cultivar showed genetic advance in the characters ear length (0.29 cm), ear circumference (0.34 cm), ear diameter (0.15 cm), seed weight per plant (3,52 g), weight of 1000 seeds (6.42 g), production per hectare (179.21 g). The increase in the mean of the six components of the results was caused by a significant positive correlation in the six characters so that an increase in one character would be followed by an increase in the other characters (Table 5).

Table 4. Value of phenotypic variance (σ^2_p), environmental variance (σ^2_e), genetic variance (σ^2_g), heritability in the broad sense (h^2_{bs}) of quantitative character of ten maize plant genotypes

Karakter	σ^2_g	σ^2_e	σ^2_p	h_{bs}^2	Criteria
Plant height	23.17	3.19	26.36	0.88	High
Days to tasseling	0.30	0.16	0.46	0.65	High
Days to silking	0.31	0.10	0.41	0.75	High
Ear height	2.36	0.82	3.18	0.74	High
Ear length	0.50	0.03	0.53	0.94	High
Ear circumference	0.28	0.01	0.29	0.97	High
Ear diameter	0.05	0.01	0.06	0.83	High
Seed weight /plant	31.73	0.88	32.61	0.97	High
Weight of 1000 seeds	160.54	21.54	182.08	0.88	High
Production per hectare	103413.77	5196.18	108609.95	0.95	High

Table 5. Correlation among yields, yield component, and agronomic characters.

	PH	DT	DS	EH	EL	EC	ED	SWP	W1000S	PPH
PH	1.00									
DT	0.82**	1.00								
DS	0.82**	0.67**	1.00							
EH	0.64*	0.66**	0.58^{ns}	1.00						
EL	0.05^{ns}	0.05^{ns}	-0.08^{ns}	-0.43^{ns}	1.00					
EC	-0.57^{ns}	-0.52^{ns}	-0.62*	-0.64*	0.67**	1.00				
ED	-0.59^{ns}	-0.47^{ns}	-0.63*	-0.65**	0.65**	0.95**	1.00			
SWP	-0.51^{ns}	-0.49^{ns}	-0.58^{ns}	-0.69**	0.75**	0.95**	0.93**	1.00		
W1000S	-0.24^{ns}	-0.30^{ns}	-0.36^{ns}	-0.59^{ns}	0.87**	0.81**	0.77**	0.90**	1.00	
PPH	-0.16^{ns}	-0.18^{ns}	-0.28^{ns}	-0.54^{ns}	0.92**	0.80**	0.80**	0.88**	0.91**	1.00

Note: PH = plant height; DT = days to tasseling; DS = days to silking; EH = ear height; EL = ear length; EC = ear circumference; ED = ear diameter; SWP = seed weight per plant; W1000S = weight of 1000 seeds; PPH = production per hectare; ** = significant at p<0.01; * = significant at p<0.05; ns = non significant

Table 6. Selection response values in four cycles of mass selection on tambin and elos cultivars for all observed characters.

Character	Cultivar									
	Tbn-0-1					Es-0-1				
	Cycle					Cycle				
	1	2	3	4	Mean	1	2	3	4	Mean
PH (cm)	-3.52	-1.46	-2.94	-1.16	-2.27	-2.64	-0.56	-3.53	-2.37	-2.27
DT (days)	0.00	-0.43	-0.44	0.00	-0.22	-0.44	0.00	0.00	-0.21	-0.16
DS (days)	-0.75	-0.25	0.00	0.00	-0.25	-0.25	0.00	-0.25	-0.50	-0.25
EH (cm)	-0.24	-1.24	-0.49	-0.47	-0.61	-0.97	-0.51	-0.51	-0.67	-0.66
EL (cm)	1.06	-0.10	0.10	0.09	0.29	0.90	0.15	0.09	0.00	0.29
EC (cm)	1.07	0.10	0.04	0.06	0.32	1.08	0.10	0.08	0.12	0.34
ED (cm)	0.30	0.06	0.02	0.03	0.10	0.41	0.04	0.05	0.12	0.15
SWP (g)	9.50	2.62	0.45	0.87	3.36	11.65	1.24	0.89	0.29	3.52
W1000S (g)	17.52	2.86	2.08	3.34	6.45	22.80	0.45	2.29	0.12	6.42
PPH (kg)	402.78	117.67	37.81	22.38	145.16	515.95	101.73	70.21	28.93	179.21

Note : PH = plant height; DT = days to tasseling; DS = days to silking; EH = ear height; EL = ear length; EC = ear circumference; ED = ear diameter; SWP = seed weight per plant; W1000S = weight of 1000 seeds; PPH = production per hectare

The selection response on the characters of plant height, days to tasseling, days to silking, and ear height has negative values on tambin and elos cultivars. The results of mass selection for four cycles on tambin cultivar showed a decrease in plant height (-2.27 cm), days to tasseling (-0.16 days), days to silking (-0.25 days), and ear height (-0.61 cm). The results of mass selection for four cycles on elos cultivar showed a decrease in plant height (-2.27 cm), days to tasseling (-0.02 days), days to silking (-0.25 days), and ear height (-0.66 cm). Mass election of the four characters in four cycles of the tambin and duko cultivars reduced the values of the four characters observed. According to Osekita and Olorunfemi (2014) that the high heritability value with a low value of genetic progress indicates that the character is most likely controlled by the action of non-additive or dominance genes.

***Conclusions*:** The method of assembling varieties using the mass selection method in this study can increase the production of two local cultivars of Madura, Indonesia (tambin and elos cultivars). The change in ten characters in mass selection for both cultivars (increase and decrease in characters) was due to the heritability value in the broad sense of ten characters having a high category value (0.65-0.97). the character of ear length, ear circumference, ear diameter, seed weight per plant, and weight of 1000 seeds can be used to indirectly select the character of production per hectare because it has a significant positive correlation. The results of mass selection on two Madura local maize for four cycles showed an increase in production of 611.20 kg/ha or an average selection response of 145.16 in the tambin cultivar, while in the elos cultivar there was an increase in production of 754.55 kg/ha or an average selection response of 179.21. Mass selection of tambin and elos cultivars in four cycles decreased days to tasseling by -1.33 days (the average selection response is -0.22) and -1.00 days (the average selection response is -0.16), respectively. Mass selection is a very effective breeding method for assembling maize varieties with early maturity and high production on tambin and elos cultivars.

***Authors' contributions*:** Achmad Amzeri:Conceived the idea, designed the study, run the analyses and wrote the article; Robit Ulum: Collect data and run the analyses.

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***Ethical statement*:** This article does not contain any studies with human participants or animal performed by any of the authors.

***Availability of data and material*:** We declare that the submitted manuscript is our work, which has not been published before and is not currently being considered for publication elsewhere

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